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Chemical Weed Control in Caladiums

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Abstract. **Eight herbicides were evaluated for phytotoxicity to field grown 'Candidium' caladiums (*Caladium* ×*hortulanum* Birdsey) in 1983. The 4 most promising or currently used herbicides were evaluated for weed control and phytotoxicity in 1984. During 1984, 4 applications of 2.24 kg/ha alachlor, 2.24 kg/ha simazine, 1.68 kg/ha oryzalin, and 0.56 kg/ha oxyfluorfen, all in combination with 1 postemergence application of 0.28 kg/ha fluazifop-butyl, were applied to caladiums. Alachlor and oxyfluorfen provided poor weed control and reduced plant vigor, tuber weights, and tuber size in 1984. Simazine provided good weed control, but reduced plant vigor and yield. Oryazlin provided excellent weed control without crop injury. Chemical names used: 2-chloro-*N*-(2,6-diethylphenyl)-*N*-(methoxymethyl)acetamide (alachlor); 6-chloro-*N,N'*-diethyl-1,3,5-triazine-2,4-diamine (simazine); 4-(dipropylamino)-3,5-dinitrobenzene sulfonamide (oryzalin); 2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl)benzene (oxyfluorfen); butyl-2-[4-[[5-(trifluoromethyl)-2-pyridinyl]oxy] phenoxy] propanoate (fluazifop-butyl).**

Weed control during the 6 to 8 month production period for caladium tubers is believed to be the greatest single cost factor involved in their production (4). Growers rely on herbicides and hand weeding, since cultivation often injures the shallow root system.

Little research has been conducted on chemical weed control in field-grown caladiums. Scudder (4) determined that 6-chloro-*N*-ethyl-*N'*-(1-methylethyl)-1,3,5-triazine-2,4-diamine (atrazine), N-N-diallyl-2-chloroacetamide (CDAA), (2-chloroallyl diethyldithiocarbamate (CDEC), and simazine provided satisfactory weed control without seriously reducing caladium tuber yields. CDEC and CDAA no longer are manufactured, whereas atrazine can be used only preemergence or in the spike leaf stage and at times results in crop injury. Weed control has been erratic with simazine and occasionally is injurious to caladiums. Alachlor never has been evaluated properly for weed control in caladiums, even though growers currently use it with mixed results. During 1983 and 1984 alachlor, simazine, and additional herbicides were evaluated for weed control and for effects on caladium tuber production.

'Candidum' caladium tuber chips (2 cm diameter) were planted 15 cm apart in 2 rows spaced 30 cm apart on 76 cm wide × 18 cm high, nonmulched beds. Soil in the experimental area was an EauGallie fine sand with 1% organic matter and a pH of 6.3. Twenty chips were planted in each plot in 1983, whereas 34 chips per plot were planted in 1984. Fertilization consisted of preplant and additional sidedress applications of an 18% N, 2.6% P, 10% K 8–9 month controlled release fertilizer for a total of 336 kg N per ha. Water was supplied continuously by seepage irrigation. A mixture of 67% methyl bromide and 33% chloropicrin (by volume) at 392 kg/ha was applied to eliminate nematodes, nondesired weeds, and soil borne diseases in both experiments. All treatment plots were hand weeded in 1983 to remove the few weeds which germinated in the fumigated soil.

Herbicide applications were made with a CO_2 back pack sprayer equipped with two 11004 flat fan nozzles operated at a pressure of 1.6 kg/cm^2 and a speed of 4.8 km/hr delivering 249 liters/ha. Crop vigor was evaluated using a pretransformed 0 to 10 rating scale (3) where 0 indicates all plants were dead and 10 represents no phytoxicity, optimum plant growth. Weed control was evaluated similarly, with 0 indicating no control and 10 representing 100% control. Tuber production was evaluated by determining fresh weight and number in each of 5 commercial grades (2).

In the first experiment, herbicides that had shown promise in preliminary work (1) were evaluated exclusively for phytotoxicity. Soil was fumigated 24 Apr., and caladium tuber chips were plants 19 May 1983. Eight treatments (Table 1) were assigned to 1.8-m long plots arranged in a randomized complete block design, replicated 4 times. Preemergence and preplant incorporated treatments were applied 19 May, and the postemergence treatment was applied 17 June, with 3 additional applications made over the top of the crop on 20 July, 7 Aug., and 13 Sept. 1983. Since grass weeds are a constant problem in caladium prdouction, fluazifop-butyl was included as a tank mix at a rate of 0.28 kg/ha, when herbicide treatments were applied 20 July and 13 Sept. Crop plant vigor was evaluated 3 times during the season. Tubers were dug and counted 30 Dec. 1983, and were weighed and graded 2 weeks later.

Only bentazon reduced plant vigor after one application (Table 1). When applied twice, oxyfluorfen, metribuzin, and bentazon reduced plant vigor to an unacceptable level (a rating of less than 7.0). Three applications of diuron, oxyfluorfen, metribuzin, and bentazon lowered vigor ratings.

Application of alachlor and oryzalin (plus fluazifop-butyl) resulted in total weights of tubers comparable to the untreated check (Table 1). Four applications of simazine reduced weights to almost one-half of the untreated check. Only metribuzin reduced the number of tubers produced. The effect of treatments on tuber production was especially noticeable when tubers were graded by size. Yields of jumbo and larger tubers were comparable to the untreated check in plots treated with alachlor, diuron, and oryzalin, whereas simazine, oxyfluorfen, and bentazon produced mostly small tubers.

In a 2nd experiment, the 3 most promising herbicide treatments from 1983, as well as simazine, were evaluated for weed control and crop effects. Soil was fumigated 17 Apr., and tuber chips were planted 8 May 1984. Two of the most common weeds encountered in caladium fields, crabgrass (*Digitaria ciliaris* (Retz.) Koel.) and pigweed (*Amaranthus hybridus* L.), were uniformly established in all test plots by overseeding each plot with 10 g of seed of each species 8 May and 10 July. Six treatments were assigned to 3.7 m long plots arranged in a randomized complete block design, replicated 4 times. Treatments were a weedy check, a hand weeded check, and preemergence applications of 2.24 kg/ha alachlor, 2.24 kg/ha simazine, 1.68 kg/ha oryzalin, and 0.56 kg/ha oxyfluorfen, all in combination with 1 postemergence application of 0.28 kg/ha fluazifop-butyl on 31 July. Simazine was included because previous research (4) indicated it was safe to use on caladiums. Although oxyfluorfen had been injurious in 1983, it was included in 1984 because it has provided good control of some problem weeds, such as some species of nightshade, in unrelated studies.

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Table 1. Effect of herbicide treatments on plant vigor after varying numbers of applications and on production of 'Candidum' caladium tubers after 4 applications. Bradenton, Fla. 1983.

		Vigor rating[z]			Tuber production/plot						
						Total	Avg no./size grade				
Treatment[y]	Rate (kg a.i./ha)	27 June (1 appl.)	30 Aug (2 appl.)	23 Sept (3 appl.)	Wt (g)	no. dug	3	2	1	Jumbo	Mammoth
Untreated check	- - -	9.0 a[x]	9.7 a	9.8 a	2704 a	19.5 a	1.5 b	3.0 abc	8.8 abc	7.5 ab	2.5 a
Alachlor	2.24	7.6 ab	9.0 ab	8.9 ab	2198 ab	18.5 a	0.8 b	1.5 c	9.2 ab	5.5 abc	2.8 a
Simazine	3.36	9.1 a	9.5 a	9.1 ab	1271 cd	18.8 a	2.0 b	5.8 a	10.0 ab	2.5 cd	0.8 bc
Diuron	1.12	9.1 a	9.0 ab	7.8 b	1522 bc	19.5 a	2.2 b	4.8 ab	10.8 a	4.5 bcd	0.8 bc
Oxyfluorfen	1.12	9.1 a	6.0 c	4.2 c	1316 cd	18.8 a	1.5 b	4.5 ab	10.8 a	4.0 cd	0.2 c
Metribuzin	0.28	7.2 ab	4.3 d	4.0 c	555 d	15.2 a	5.0 a	4.5 ab	5.0 c	1.5 d	0.0 c
Oryzalin	1.12	8.0 ab	9.1 ab	9.8 a	2806 a	19.2 a	1.0 b	0.8 c	6.5 bc	8.8 a	3.0 a
Bentazon	0.84	6.8 b	5.6 cd	7.8 b	1242 cd	17.5 a	1.5 b	4.8 ab	9.2 ab	3.5 cd	0.2 c

[z]Vigor was evaluated using a 0 to 10 rating scale where 0 indicated all plants were dead and 10 represented no injury, optimum growth.
[y]Herbicides were initially applied preemergence, except metribuzin which was applied preplant incorporated and bentazon which was applied postemergence. Subsequent applications were made postemergence over the top of the crop with 0.28 kg a.i./ha fluazifop-butyl included as a tank mix on 20 July and 13 Sept.
[x]Mean separation within columns by Duncan's new multiple range test, 5% level.

Two additional applications of each preemergence herbicide were made over the top of the crop 11 July and 3 Oct.

Caladium plant vigor and weed control were evaluated 4 times during the season. Tubers were dug and counted 3 Dec. 1984, and were weighed and graded 2 weeks later.

Caladium plant vigor steadily decreased with each successive application of the herbicide treatments, except with oryzalin (Table 2). One application of simazine reduced plant vigor relative to the hand weeded check. After 2 applications of each treatment, alachlor, simazine, and oxyfluorfen each reduced plant vigor; this trend continued through harvest. Application of fluazifop-butyl did not influence vigor ratings (Table 3).

Crabgrass control was excellent with all herbicides after 1 and 2 applications (Table 3). Application of fluazifop-butyl in late July to control emerged crabgrass, combined with application of the preemergence herbicides earlier in the month, resulted in excellent crabgrass control in herbicide treated plots at the 3rd rating date. By late season (Nov.), crabgrass control was less with alachlor and oxyfluorfen than with hand weeding or oryzalin.

Table 2. Effect of herbicide treatment on vigor[z] of 'Candidum' caladium plants after varying numbers of applications. Bradenton, Fla. 1984.

Treatment[y]	Rate (kg a.i./ha)	22 June (1 appl.)	31 July (2 appl.)	21 Sept. (2 appl.)[x]	7 Nov. (3 appl.)[x]
Weedy check	- - -	8.1 ab[w]	4.5 cd	3.0 c	3.0 d
Hand weeded check	- - -	9.0 a	9.2 a	8.6 a	8.6 a
Alachlor	2.24	8.1 ab	7.0 b	6.0 b	6.5 b
Simazine	2.24	7.9 b	5.8 bc	5.2 b	4.0 cd
Oryzalin	1.68	8.4 ab	9.0 a	8.5 a	9.4 a
Oxyfluorfen	0.56	8.6 ab	3.8 d	5.0 b	4.4 c

[z]Vigor was evaluated using a 0 to 10 rating scale where 0 indicated all plants were dead and 10 represented no injury, optimum growth.
[y]Initial herbicide applications were preemergence with subsequent applications made over the top of the crop plants. Fluazifop-butyl (0.28 kg a.i./ha) was applied to each herbicide treated plot 31 July 1984.
[x]Indicates numbers of applications of preemergence herbicides, plus one application of fluazifop-butyl.
[w]Mean separation within columns by Duncan's new multiple range test, 5% level.

Table 3. Effect of herbicide treatments on weed control in 'Candidum' caladiums after varying numbers of applications. Bradenton, Fla. 1984.

	Rate	Crabgrass control rating[z]			Pigweed control rating[z]		
Treatments[y]	(kg a.i./ha)	1 appl.	2 appl.[x]	3 appl.[x]	1 appl.	2 appl.[x]	3 appl.[x]
Weedy check	- - -	7.0 b[w]	2.5 b	0.0 d	0.0 c	0.0 e	0.0 d
Hand-weeded check	- - -	10.0 a	10.0 a	10.0 a	9.6 a	10.0 a	10.0 a
Alachlor	2.24	9.7 a	9.6 a	7.8 c	6.9 b	5.2 c	5.8 c
Simazine	2.24	10.0 a	9.9 a	9.1 ab	9.8 a	8.2 b	8.7 b
Oryzalin	1.68	10.0 a	10.0 a	9.8 a	9.6 a	8.4 b	10.0 a
Oxyfluorfen	0.56	10.0 a	9.6 a	8.5 bc	1.0 c	4.0 b	6.8 c

[z]Weed control was evaluated on a 0–10 scale where 0 indicated no control and 10 represented complete control.
[y]Initial herbicide applications were preemergence with subsequent applications made over the top of the crop plants. Fluazifop-butyl (0.28 kg a.i./ha) was applied to each herbicide treated plot 31 July 1984.
[x]Indicates numbers of applications of preemergence herbicides, plus one application of fluazifop-butyl.
[w]Mean separation within columns by Duncan's new multiple range test, 5% level.

Alachlor and oxyfluorfen provided very poor control of pigweed for the entire experiment (Table 3). Pigweed control was excellent with simazine and oryzalin at the first evaluation, but decreased after that time. A 3rd application of simazine did not improve pigweed control to the same level as obtained with oryzalin or hand weeding late in the season. By this time, control with oryzalin had improved due to chemical girdling and inhibition of root growth of pigweed plants in contact with treated soil.

Herbicide treatments did not affect the number of tubers dug (Table 4). Weed competition in the weedy check was strong enough to reduced tuber yields. Weight of tubers was highest with oryzalin and hand weeding. Tuber weights with alachlor and simazine were one-third or less of what they were with oryzalin and were similar to the weedy check. When tubers were graded by size, data confirmed that oxyfluorfen, simazine, and alachlor reduced tuber size, while significantly more number 1 and jumbo tubers were produced with oryzalin and hand weeding.

The standard use of alachlor did not provide adequate season-long weed control and reduced tuber yields. Yield reductions with alachlor and oxyfluorfen were thought to be due to both chemical injury and poor weed control which allowed greater weed competition, principally from pigweed. Apparently more chemical injury was obtained with oxyfluorfen than with alachlor, since vigor of plants treated with oxyfluorfen was substantially reduced at the 2nd evaluation; yet, weed control was similar throughout the experiments. These experiments indicated chemical phytotoxicity from simazine was the primary cause of yield reduction, since weed control was acceptable for the duration of the experiment and vigor was reduced with the first application of simazine. Previous research (4) indicated simazine was safe to use on caladiums; however, that research was conducted on an organic soil with very high cation exchange capacity which would bind more of the herbicide than would the fine sand soil on which the current research was conducted.

Two of the most ubiquitous weeds in ca-

Table 4. Effect of 3 applications of each herbicide treatment on tuber production by 'Candidum' caladiums. Bradenton, Fla. 1984.

Treatment[z]	Rate (kg a.i./ha)	Tuber production/plot Wt (g)	Total No. dug	Avg. no./size grade 3	2	1	Jumbo	Mammoth
Weedy check	- - -	495 b[y]	27.2 b	12.0 b	13.0 a	1.5 cd	0.0 c	0.0 a
Hand-weeded check	- - -	2549 a	35.5 a	5.0 c	8.2 ab	19.8 a	3.0 ab	0.5 a
Alachlor	2.24	1227 b	30.2 ab	5.2 c	12.2 a	13.2 b	0.2 bc	0.0 a
Simazine	2.24	1012 b	29.5 ab	9.0 bc	13.0 a	5.5 c	0.8 bc	0.0 a
Oryzalin	1.68	3030 a	33.8 a	4.8 c	4.2 b	21.8 a	5.5 a	0.2 a
Oxyfluorfen	0.56	513 b	31.8 ab	17.2 a	13.8 a	0.2 d	0.0 c	0.0 a

[z]Indicated herbicides were applied 3 times, plus 0.28 kg a.i./ha fluazifop-butyl was applied once to herbicide treated plots.
[y]Mean separation within columns by Duncan's new multiple range test, 5% level.

ladium production, crabgrass and pigweed, can be controlled with applications of 1.68 kg/ha oryzalin without decreasing tuber weight and size. As many as 4 applications can be applied without injury. Where emerged crabgrass is a problem, 0.28 kg/ha fluazifop-butyl can be applied without any phytotoxicity.

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A Nondestructive Method for Measuring Root System Surface Area

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Additional index words. *Euphorbia pulcherima*, poinsettia, nonionic polymer, gravimetric measurement

Abstract. **A method is described for obtaining nondestructive estimates of root system surface area. The technique is based on the assumption that the larger the root system, the more gel of a given viscosity will adhere to it. The correlation between gel adherence and 5 parameters of root system size (root length, root fresh weight, root dry weight, root volume, and root surface area) is established.**

Experimentation on the growth of root systems can be enhanced by using a growing system that allows repeated access to the roots for nondestructive estimates of root growth. In experiments concerned with root growth and development, the root surface area would be valuable but is seldom used due to the time consuming nature of its measurement. The parameters commonly used to express root growth and development are root number, fresh weight, dry weight, diameter, volume, length, and the number of root tips. In most instances, these are obtained destructively (1). Root volume, although frequently obtained simply and nondestructively (2, 4, 5), yields information of limited value because plants having large roots may be volumetrically equivalent to plants having large numbers of small fibrous roots, and the surface or absorbing areas must be quite different.

We have constructed aeroponic growing facilities which periodically fog the root system with a nutrient fog (500 psi), in order to have ready access to the plant's root system. This facility was preferred to hydroponic systems because the root morphology of the plants grown in the aeroponic system reflected that of plants grown in potting media (1). Also, a much smaller volume of water and nutrients can be distributed evenly to the plant's root system. The aeroponic growing technique led to the need to develop a nondestructive method for the repeated estimate of root growth. It is the purpose of this paper to describe the methodology and compare it to classic measurements of root system growth and development.

The method described is a "gravimetric method" which estimates root surface area based upon the amount of gel adhering to the surface of a plant root system. It is based upon the assumption that the larger the root system, the more gel of a given viscosity will be removed from a reservoir, and the amount of gel removed can be measured directly as the reduced weight of the gel reservoir.

Gravimetric techniques using a viscous calcium nitrate solution have been described previously (2). However, this technique is intended for dried roots and is not suitable for repeated measurements of living root systems.

Plant material. Poinsettia cuttings (*Euphorbia pulcherima*, 'Annette Hegg Brilliant Diamond') were propagated under mist in Oasis rooting cubes until callus was well developed. Cuttings were removed from the Oasis cubes after callus formation and placed in plastic bags. The cutting base was inserted into the aeroponic chamber and fogged with clear water until roots were visible. After root development, plants were fogged with a nutrient solution and the plastic bags removed from the shoot.

Gel construction. Hydroxyethylcellulose water soluble nonionic polymer Natrosol 250 HHR (0.65 gm/l) was added slowly to 2 liters of deionized distilled water and vigorously stirred with a magnetic stirring bar. Water temperature was 22°C and the pH was between 6.5 and 7.0. The solution was allowed to stir for about 1 hr or until a final viscosity of 650 centipoises (cps) at 25° was achieved as determined with a Fischer MacMichael viscosimeter using a No. 30 wire. All measurements of gel adhesion to the root system were made at a gel temperature of 22° ± 1°.

Root system parameter measurement. Plants were removed at weekly intervals from the aeroponic growing chambers. A plastic container with 2 liters of gel was placed on a digital balance and the initial container plus gel weight was recorded. The entire plant root system was rinsed in deionized water

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